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Agricultural Research

Sterling B. Hendricks— USDA Basic Research Pioneer

"Freedom to inquire into the nature of things is a rewarding privilege granted to a few by a permissive society."

These humble words by Sterling B. Hendricks only hint at the transcendent intelligence and inventiveness of this internationally renowned USDA scientist and leader of the former ARS Mineral Nutrition Pioneering Research Laboratory, Beltsville, Md. With his death on January 4, 1981, the world lost a pioneer in basic research.

Dr. Hendricks' quest for knowledge about "the nature of things" led him from fundamental research on crystal structures and X-ray diffraction analysis, to the discovery that clay is the most important component of soil, to breakthrough work in hydrogen bonding, to the discovery that plant germination and flower are controlled by phytochrome. These findings enhanced our understanding of the nature of soils and the behavior of plants—knowledge essential to the development of soil and water conservation practices, the control of weeds, and the adaption of crops to particular environments. By his untiring exploration of the unknown, he leaves a legacy and a challenge to those scientists who follow him in pursuit of basic knowledge.

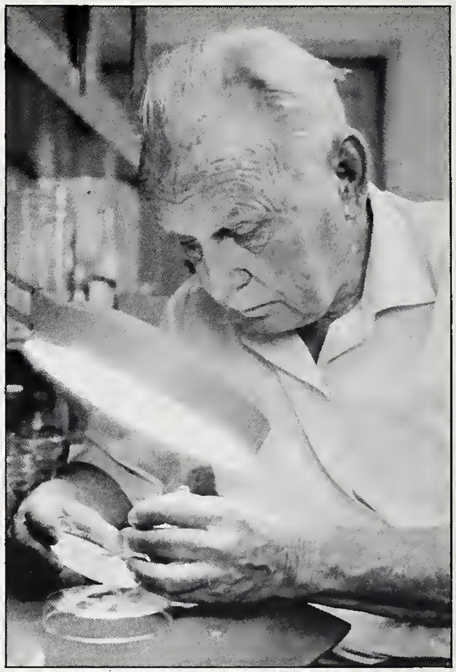
Dr. Hendricks was a man who climbed and reached the pinnacle—in both professional and personal endeavors. In 1976, President Gerald R. Ford presented the National Medal of Sciences to Dr. Hendricks. As recipient of the first Rockefeller Public Service Award for Science and Technology in 1960, he was honored for "pioneering research on the soils and plants on which human life depends . . . with this increased knowledge, civilization is gaining in its fight against hunger." In 1958, he received one of the first Gold Medal Presidential Awards for Distinguished Civilian Service—the highest honor given to career government employees. An expert mountain climber, in 1942 Dr. Hendricks was a member of the third party to conquer Alaska's Mount McKinley, the highest mountain in North America.

Dr. Hendricks began his 42-year career with USDA in 1928 as an associate chemist at the Fixed Nitrogen Laboratory. Much of our modern progress in understanding soil is built on a series of experiments in which Dr. Hendricks took the lead. He established that clay particles in a soil have an identifiable crystalline structure. This finding enabled scientists to understand the chemical processes through which soils make their elements available to plants and to recognize important differences among soils that otherwise seem to have the same composition.

The prominent reseachers' skill in using X-ray diffraction for analysis led to an important study of the composition of fertilizers early in his career. In 1931, Dr. Hendricks showed that phosphate rock, the foundation of the phosphate fertilizer industry, is composed of five particles of the mineral apatite. His later studies of phosphate contributed to the development of present methods of manufacturing fertilizers and feed supplements.

One of this century's greatest advances in plant physiology resulted from a joint research project on photoperiodism by Dr. Hendricks and Dr. Harry A. Borthwick, leader of the Plant Physiology Pioneering Research Laboratory. Their discovery that the development of plants is controlled by the action of phytochrome, a pigment responsive to light, explained mysteries of flowering and seed germination with far-reaching implications to agriculture. These two researchers received the 1962 Hoblitzelle National Award for this outstanding contribution to American agriculture.

The author of more than 200 scientific papers, Dr. Hendricks brought to research training and expertise in chemistry, physics, mineralogy, and plant physiology. The noted scientist was born at Elysian, Tex., in 1902. He received his B. Ch. E. degree in chemistry and mathematics in 1922 from the University of Arkansas. After studying geology and chemistry at the University of Iowa, Dr. Hendricks earned his M.S. degree in 1924 from the Kansas State Agricultural College. In 1926, he was awarded the doctoral degree in chemistry, mathematical physics, and physics from the California Institute of Technology.



A member of the National Academy of Sciences, Dr. Hendricks was chairman of its botany section. He served as president of the American Mineralogical Society and of the Society of Plant Physiology, and was a former fellow of both the American Society of Agronomy and the American Physics Society.

Other honors awarded Dr. Hendericks were the USDA Distinguished Service Award, the Geological Society of America Day Medal, an LLD. degree from the University of Arkansas, the Science Award of the Washington Academy of Sciences, the Hillebrand Prize of the Chemical Society of Washington, the Stephen Hales Award for Plant Physiology, and the Finsen Award of the International Society of Photo Biology.

Dr. Hendricks retired from USDA in 1970. But he never retired from research, and was a research consultant to the Department at the time of his death. Master scientist in his own right and master mentor to numerous young scientists during more than a half century of service, Sterling B. Hendricks' mark upon agriculture will endure.

Contents

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Cover: Hydrilla, an aquatic weed, is spreading rapidly throughout southern California and Florida waterways, threatening water flow to irrigation districts, municipalities, and drainage systems. Hydrilla branches profusely—just one fragment of this shoot can break off, form roots, and produce a new plant. Scientists are experimenting with chemicals and a sterile hybrid carp species to control hydrilla's spread. Our articles begin on page 4 (980X1094-29a).

Hydrilla—A Costly and Destructive Weed

In 1977, a few strands of hydrilla—an aquatic weed—were spotted in California's All American Canal. Now, it infests more than 400 miles of important southern California waterways.

The State of California, as well as SEA and other federal and state research and action agencies are examining various chemical and natural methods to stop the weed's rampant invasion. The state has authorized $2.5 million for hydrilla control, to be spent over 5 years.

Hydrilla is native to central Africa. Scientists speculate that aquarium owners unknowingly contributed to its spread as a weed pest in this country. About 1960, hydrilla was gathered from a Florida river and sold to aquarium suppliers throughout the country as an aquarium plant. Later, aquariums containing hydrilla probably were emptied into water systems. Boats, bait pails, and wildlife may also have aided in the weed's widespread distribution.

Left uncontrolled, hydrilla could continue to spread, infesting other canals and waterways in California and in the Lower Colorado River Region, including Arizona and Mexico. As a result, fishing, boating, and swimming would become difficult or impossible in many areas. Restricted water flow greatly increases threat of flooding with possible life and property losses. Hydrilla would then obstruct water flow to municipalities, irrigation districts, and drainage systems.

The weed has been found in six California counties, including Imperial, San Diego, Riverside, Santa Barbara, Monterey, and Yuba. However, hydrilla's immediate threat is to Imperial Valley crops which grossed more than $837 million in 1979.

Above: Lars Anderson, plant physiologist, scoops a tangled armful of hydrilla from the bottom of Thistle Main Canal near El Centro, Calif. This sample is from a dense mass lining the canal. Anderson is checking effects of recent chemical treatment (980X1094-9a).

After receiving an emergency exemption from the Environmental Protection Agency (EPA), personnel from the California Department of Food and Agriculture (CDFA) and the Imperial Irrigation District applied an organo-copper herbicide to infested areas of the All American Canal by helicopter and truck in 1979. Additional treatments were made in 1980.

However, this chemical does not kill the plant—it only removes some of the new growth, not the roots or reproductive structures (tubers). Rapidly flowing canal water makes control even more difficult by limiting the time that hydrilla is exposed to the herbicide.

Scientists are looking for more potent chemicals. But, because infested canals carry water for drinking, irrigating, and sport fishing, they must closely examine each potential herbicide before it is used. Proving that such chemicals are safe to humans, livestock, crops, and wildlife, as well as effective in stopping hydrilla's rapid spread, takes time, money, and vast technical expertise.

Lars W. J. Anderson, plant physiologist, Davis, Calif., plans, coordinates, and directs SEA's involvement in the program. He and other scientists at

Top Left: Scraping canal bottoms and sides is a temporary, costly, and time-consuming method of controlling hydrilla. This process loosens polluting silt and breaks off plant parts, which aids in hydrilla's spread (980X1092-6).

Above: Thick mats of hydrilla have severely reduced the capacity of this 58-acre reservoir in El Centro, Calif. This aquatic weed has impeded water flow in connecting canals by up to 90 percent (0980X1098-12).

Davis, Calif., are using a model irrigation canal to duplicate actual field conditions and evaluate new chemicals. They are studying uptake and translocation of herbicides in hydrilla to determine contact time and optimum application time required for weed control. Anderson and staff are also researching the use of naturally occurring chemicals that control hydrilla growth and reproduction. Duplicates of these chemicals applied to hydrilla could stop reproduction, or at least slow plant growth.

The SEA Imperial Valley Conservation Research Center at Brawley is the focal point for field research. There Anderson and staff evaluate new aquatic herbicide effectiveness and study the reproductive capacity of hydrilla.

Other government agencies are also probing the hydrilla problem. In Denver, Colo., Tom Jackson heads a U.S. Department of Interior Fish and

Top left: Anderson, left, and Valerie van Way, State of California employee, bag hydrilla samples. The weed's biomass and shoot length measure effect of chemical treatment on growth rate (980X1097-10).

Top: Carlos Nuss, standing and Mike Remington, both State of California seasonal employees, drain water and silt from hydrilla tubers. Counting tubers left in the sample after chemical removal of top growth helps determine chemical treatment's effect on tuber production (980X1102-26).

Above: Found 2-to-10 inches under canal bottom soil, tubers—bulb-like structures from which hydrilla reproduces—are protected from chemicals applied to top growth, making hydrilla's spread difficult to control (980X1098-28a).

Wildlife program to select fish that agressively eat hydrilla. But scientists are proceeding very cautiously in this area. The wrong fish could drastically affect the balance of nature. If these fish adapt too well to infested waterways, they could overpopulate and crowd out more desirable game fish.

Researchers at Denver are currently examining a hybrid cross between bighead carp and grass carp. In tests to date, the hybrid appears to be sterile, thus its population could be carefully controlled.

Gene Otto leads U.S. Interior's Water and Power Resources Services research in Denver to determine if this hybrid has potential for controlling hydrilla growth in Imperial and Riverside counties, Calif. This research is in cooperation with SEA, APHIS, California Department of Food and Agriculture, and Imperial County. If the fish are proven to be 100 percent sterile and are effective against hydrilla, they could become a useful tool in controlling the weed.

The University of California and the U.S. Department of Interior's Water and Power Resources Service are also working to control California's hydrilla infestation.

Hydrilla also poses a threat to the state's $225 million rice industry. Estimates indicate that if the weed becomes established in the Central Valley's rice-producing areas, annual losses of millions of dollars would occur in 20 years.

In addition to California, other states with known hydrilla infestations include Florida (see accompanying article), Georgia, Alabama, Mississippi, Louisiana, Texas, plus Iowa and Wisconsin in the north. And, it is probable that hydrilla is present, but unidentified, in other states.

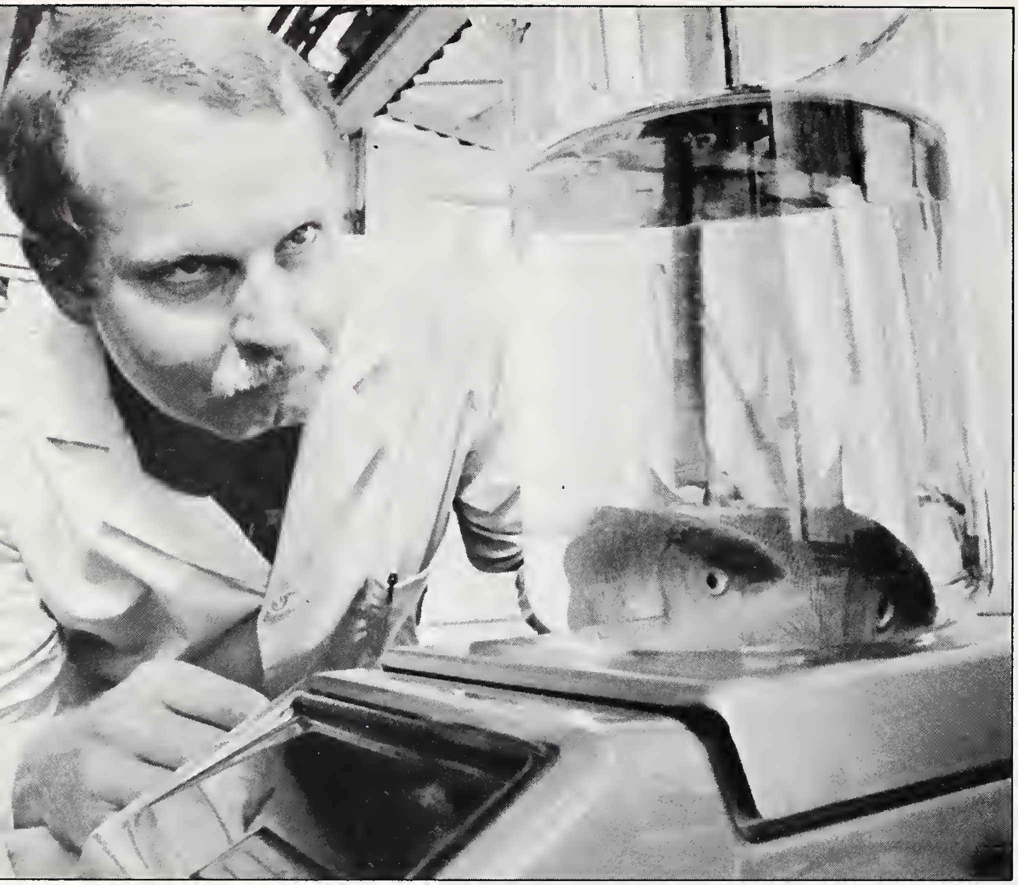
Dr. Anderson's address is USDA-SEA, Botany Department, 206 Robbins Hall, University of California, Davis, CA 95616.—(By Dennis Senft, SEA, Oakland, Calif.)

Top: At the Brawley Lab, Calif., Anderson, right, and Remington, center, examine hydrilla growth. Shoot length is recorded by Carlos Nuss (980X1107-26).

Above: After inserting hydrilla in an oven to dry, Remington and fellow researchers will record its dry weight (980X1101-15).

Left: If scientists know where hydrilla will most likely grow, they can utilize preventive controls. Water temperature may affect hydrilla growth and photosynthetic rates. Tom Jackson, fishery research biologist, Denver, Colo., examines samples from Florida and California, that will be tested to learn more about these relationships (1080X1359-26).

Fighting Hydrilla in Florida



Top: Jackson weighs sterile hybrid grass carp to check growth rate. Although not yet released, this fish eats hydrilla and could control its spread (1080X1359-14).

Above: This 8-inch-long sterile grass carp cannot reproduce to crowd out native fish species. Use of this fish—a cross between a female grass carp and a male bighead carp—has just been legalized for hydrilla control in Florida waterways (1080X357-8).

Hydrilla infests approximately 25 percent of Florida's waterways, where it first began its rapid spread throughout the United States about 20 years ago. Researchers at the Aquatic Weed Control Laboratory in Fort Lauderdale are fighting its rampage with a two-pronged approach—chemical and biological control.

According to Florida Department of Natural Resources officials, within the next 5 to 10 years, 90 percent or more of Florida's 2.5 million acres of waterways will encounter problems related to hydrilla. Partial control will cost more than $100 million annually at that level. The state is now paying $10 to $12 million annually for partial control of only 5 percent of currently infested waterways.

"We do fundamental work on the plant itself, looking for weak points in its life cycle," says Kerry K. Steward, SEA plant physiologist at the laboratory. Screening thousands of chemicals for controlling hydrilla growth since the late 1950's, researchers in Fort Lauderdale have found some that are effective but not yet registered for use by the Environmental Protection Agency (EPA), says Steward.

"One big problem with controlling hydrilla is that it can regrow from propagules in the mud," Steward says. "Hydrilla reproduces from tubers on the end of rhizomes, or from rootstocks. Plants regrow within 6 weeks of control," he says.

Chemicals that prevent regrowth and persist in the environment have the greatest potential for controlling hydrilla. Hexazinone and fenac, which provide control for more than 18 months are the two most promising chemicals in this category.

Another chemical, Dichlobenil, is effective in preventing hydrilla reproduction although it is not persistent. Work is underway to artificially increase Dichlobenil's persistence and length of control through formulation in controlled-release carriers.

If successful, this approach would be preferable to others that use persistent, water-polluting chemicals such as fenac. Dichlobenil dissipates from the water rapidly, lessening environmental hazards and allowing more immediate reuse of water.

Biological control agents such as insects, pathogens, and fish also are under study, says Ted Center, SEA entomologist at the Ft. Lauderdale laboratory.

Through surveys, SEA researchers are studying insects that inhabit and attack hydrilla. This cooperative effort with the Army Corps of Engineers, Aquatic Plant Control Research Program, and the University of Florida has found that *Parapoynx diminutalis* does some damage.

The larvae of this moth were discovered accidentally in 1976 by a technician preparing plastic pools for herbicide-testing programs. He noticed "worms" eating the weed. (*Agricultural Research,* May 1976, p. 14.)

"Midge larvae may be potentially useful," Center adds. "If they build up to high populations, the hydrilla declines."

Foreign surveys, says Center, are also helpful. *Parapoynx rugosalis* does tremendous damage to the weed in Panama and shows potential for control in the United States. This insect is being tested by SEA researchers in Gainsville, Fla., to ensure that it attacks hydrilla only.

Foreign surveys for natural enemies of hydrilla are also being initiated in Africa, Australia, India, and Southeast Asia, says Center.

Dr. Ted D. Center and Dr. Kerry K. Steward are located at the Aquatic Weed Control Research Laboratory, 3205 S. W. 70th Avenue, Fort Lauderdale, FL 33314.—(By Peggy L. Goodin, SEA, New Orleans, La.)

Cattle on Hybrid Rangeland

What kind of grass do these cattle prefer? The answer could help researchers determine which new grass species to develop commercially. (Photo courtesy Grant Heilman.)

Cattle have their likes and dislikes regarding range grasses, and SEA scientists are attempting to identify this "preference factor" with hopes of using it in future breeding programs.

SEA plant physiologist Richard S. White, along with range scientist Pat O. Currie, both at Miles City, Mont., and SEA plant geneticist Kay H. Asay, Logan, Utah, conducted tests on 75 experimental lines of hybrid range grasses with virtually equal nutritional value. The cattle grazed some lines heavily and some not at all.

"Perhaps now, cattle can help determine which new species of grasses should be developed commercially and which should be dropped," says White.

For the tests, a field was planted with 50 plants from each hybrid line. A mixture of Herefords and other cattle breeds were released into the field two at a time, while the scientists observed their eating patterns. The cattle grazed mornings and afternoons, each time in different pairs to avoid one-animal-following-the-other situations.

"At first, the animals meandered about, grazing everywhere," says White, "but gradually they returned to concentrate on specific plants in specific lines."

Of the 75 hybrids studied, 12 lines were seldom chosen by the cattle. The number of bites taken from the remaining 63 lines were counted and compared to determine the favorites.

The researchers are now running more intensive trials to see if the cattle still prefer their previous favorites. If the favorites remain the same, they will be analyzed and compared to less preferred plants to determine the reason for the preference.

Hopefully, the preference factor can be identified and geneticists can include it among the qualities looked for in range grass breeding programs.

Dr. White and Dr. Currie are located at the Livestock and Range Research Station, Route 1, Box 3, Miles City, MT 59301. Dr. Asay is located at Room 207, Utah State University, UMC 48, Agricultural Science Bldg., Logan, UT 84322.—(By Lynn Yarris, SEA, Oakland, Calif.)

"Switching Off" Insects

Uric acid poisoning could help halt destructive eating binges of the tobacco hornworm. By discovering what controls its natural uric acid storage, scientists hope to stimulate fatal waste accumulation in the larvae leading to its demise (379X289-17).

Inducing insects to poison themselves with uric acid produced in their own bodies is seen as a possible control method by a team of SEA scientists at the Metabolism and Radiation Research Laboratory, Fargo, N. Dak.

The tobacco hornworm is the insect species being used in the uric acid metabolism studies. This insect, which destroys tobacco and some valuable vegetable crops, has a mechanism for switching from excreting to storing uric acid as it prepares to change from its larval (caterpillar) to its pupal (cocoon) form.

Uric acid is the major waste product of nitrogen metabolism in the larval form in this and many other insect species.

Any disruption of the "switch" mechanism that controls the shift from excretion to storage of uric acid could result in the insect's death by building up higher than normal levels of uric acid in its hemolymph (the insect equivalent of blood), biochemist James S. Buckner explains.

Late in the fifth instar (stages of growth in the larval form of the insect), the tobacco hornworm larvae stop feeding, abruptly stop excreting, and begin what is known as the wandering stage as they search for a site to pupate.

During this wandering stage, the insect continues to produce uric acid. But a mechanism probably controlled by the molting hormone, ecdysone, "switches off' excretion and diverts the uric acid into storage until just before the adult moth emerges. The pupal form lasts about 20 days—or several months for pupae that become dormant to overwinter.

Once Buckner has completed his current studies on the role of hormones in uric acid metabolism, the search for the specific chemical compound to inactivate the "switch" can begin. If a chemical is identified, its

practical use in controlling the insect can then be evaluated.

SEA entomologist John P. Reinecke, Buckner, and aide Sharon R. Grugel earlier had used time-lapse cinematography to precisely record, for the first time, all the events in the development and behavior of the tobacco hornworm from the egg through the pupation.

They noticed, as had other researchers, that midway through the larval feeding stage some tobacco hornworm larvae produced fecal pellets coated with a chalky material. Buckner, technician June M. Caldwell, and Reinecke subsequently identified the material, called "frosted frass," as either crystalline uric acid or a form of urate salt.

In the insect, organs known as Malpighian tubules remove uric acid and other organic materials from the circulating hemolymph and release these materials to the lower gut where they are excreted. Buckner and associates found that the uric acid content of the feces rose starting in the fourth instar and continuing into the fifth instar. At higher concentrations, and depending on the insect diet, "frosted frass" might be observed during the fifth instar.

Buckner and Caldwell then showed that uric acid synthesis continued through the feeding, wandering, and prepupal stages of the fifth instar in the hornworm larvae. But excretion stopped at the beginning of the wandering stage.

They confirmed the observations of others that an organ known as the fat body is the major storage site for uric acid during the last 5 days before pupation. The fat body also synthesizes uric acid.

Buckner says the abrupt change in the fat body's role from synthesizing uric acid and releasing it, to synthesizing and storing it, is a timed event, probably under the control of hormones. Since it was known that releasing the hormone ecdysone initiates the wandering stage at about this time, ecdysone was implicated in triggering the shift from excretion to storage of uric acid.

The biochemist demonstrated ecdysone's involvement with fifth-instar larvae tied just behind the thorax. This tying procedure shuts off the opening from the glands that produce ecdysone, thus separating the fat body from the source of ecdysone. Tying was done just before another hormone from the brain was due to be released —a hormone that triggers the release of ecdysone.

Forty-eight hours after tying, these larvae had not stored uric acid in their fat bodies, and similarly tied larvae given an injection of ecdysone showed significant increases in uric acid in their fat bodies.

Buckner's later research seems to implicate a second hormone, the juvenile hormone in the "switch." When Buckner applied juvenile hormone to tied larvae, the storage of uric acid in the fat body was markedly reduced. The inhibitory properties of juvenile hormone may explain why the "switch" to uric acid storage does not occur during molts between larval instars—when ecdysone is released in the presence of juvenile hormone—but does occur during the larval-pupal molt —when juvenile hormone is absent.

If inducing uric acid poisoning can eventually control insects, the tobacco hornworm may not be the only target insect. The researchers believe a "switch" mechanism may exist in all insects undergoing complete metamorphosis.

Dr. James S. Buckner and Dr. John P. Reinecke are located at the Metabolism and Radiation Research Laboratory, P.O. Box 5674, State University Station, Fargo, ND 58105.—(By Walter W. Martin, SEA, Peoria, Ill.)

Viruses Attack Black Cutworm

Scientists, searching for ways to control the black cutworm in corn have discovered that two nuclear polyhedrosis viruses (NPV) infect the pest.

"This is the first known instance of these NPV replicating in the black cutworm," said Leslie C. Lewis, research entomologist at the SEA Corn Insects Research Laboratory, Ankeny, Iowa.

One of the viruses is commonly found in *Rachiplusia ou,* a looper species which attacks mint. This virus was added to the food of the black cutworm. It appeared the pest was infected, but the scientists at Ankeny needed confirmation.

Jean R. Adams, research entomologist at the Insect Pathology Laboratory, Beltsville, Md., with the aid of the electron microscope confirmed the infection —the first time a viral infection in the black cutworm has been confirmed.

The second NPV to successfully infect the cutworm, of several the researchers tried, was found in *Autographa Californica,* the alfalfa looper.

Timothy B. Johnson, a graduate student working with Lewis, increased the stock of viruses. When the viruses were applied to corn seedlings, they significantly reduced leaf cutting, number of plants damaged, and seedling cutting by the black cutworm, Lewis said.

The scientists have begun field tests of the viruses and hope they will become part of a population suppression system, in combination with other disease organisms of the black cutworm which the laboratory is testing.

Because viruses can only replicate in living tissue, they are difficult to produce in large volume, Lewis pointed out.

Dr. Lesie C. Lewis is located at the Corn Insects Research Unit, Route 3, Ankeny, IA 50021. Dr. Jean R. Adams is located at the Insect Pathology Laboratory, Room 214, Building 011A, BARC-West, Beltsville, MD 20705.

Top: Preparing beef cattle manure for fermentation, Mike Overturf, agriculture research technician, combines manure and water in a mixing vat at the Methane Pilot Plant, Clay Center (678W725-22).

Above: To increase methane production, ground straw is added to manure and water mixture by Steve Robinson, operations assistant. (1080W1219-23).

Above: Straw is ground into particles small enough to travel through the Methane Pilot Plant as part of the manure mixture. Agriculture research technician, Brad McConnel, foreground, loads straw into the mill, while Jim Chapman, agriculture research technician, collects processed straw (108W1216-6).

"Beef cattle feedlots larger than 1,500 head, we believe, can economically produce methane and protein from manure," says SEA agricultural engineer Andrew G. Hashimoto.

Hashimoto leads a research team conducting laboratory and pilot-scale studies on converting manure to methane and protein by thermophilic anaerobic fermentation at the Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Nebr. "Thermophilic" indicates the process is carried out at high temperature, and "anaerobic" describes the oxygen-free atmosphere under which fermentation takes place.

In the best designed plants under optimum conditions for fermentation, Hashimoto says, manure from one steer can produce about $20 worth of methane and about $40 worth of protein a year.

Assuming that 50 percent of the effluent heat can be recovered and cycled back into the fermentation system, only about 10 percent of the methane produced is needed to maintain fermentation temperature. The remaining 90 percent might replace fossil fuels on the farm for steam flaking of feed, heating buildings, running irrigation pumps, or other uses. Large, strategically located feedlots might produce and sell pipeline quality natural gas or sell methane for electrical generation.

The process, Hashimoto explains, uses bacteria naturally present in manure to convert the manure to methane gas and more bacterial cells. These protein-rich bacterial cells remain in the effluent.

Hashimoto, agricultural engineer Yud-Ren Chen, chemist Ronald L. Prior, and microbiologist Vincent H. Varel found that the effluent (3 to 4 percent solids) has a crude protein equivalent of about 60 percent. This effluent can be used as a protein supplement in livestock feed or possibly as fertilizer.

The total yearly cost—equipment, labor, and utilities—for producing methane decreases from $70 per steer for a 1,000-steer feedlot to $15 per steer for a 100,000-steer feedlot, Hashimoto says.

Beef cattle manure is economically more feasible for methane conversion by fermentation than other forms of manure or plant residues.

Manure generated at large confinement feedlots need not be transported long distances to the fermentor. The fermentation system helps control pollution, odors, and pests, in addition to helping solve a waste-disposal problem.

Fermentation technology has been applied for years in domestic sewage treatment and for energy recovery in developing countries. Anaerobic fermentation occurs naturally in such environments as pond sediments and the gastrointestinal tracts of animals.

SEA microbiologist Robert A. Rhodes conducted initial laboratory studies on conversion of beef cattle manure to methane at the Northern Regional Research Center, Peoria, Ill. Pilot-scale research partly funded by the National Science Foundation (NSF) and Department of Energy (DOE) then began at Clay Center.

The Clay Center research team directed by Hashimoto has concentrated on identifying optimum fermentor design and operating conditions for beef cattle manure. Operation of the fermentor may be manipulated three ways:

—The temperature at which fermentation occurs—86° through 149°F (31° through 65°C).

—The loading rate, or amount of waste added to the fermentor daily—0.015 to 0.15 pound of dry manure per gallon of fermentor volume (2 to 20 grams per liter.)

—The retention time, or length of time the waste remains in the fermentor—3 to 18 days.

The effect of temperature on methane production depends on retention time and loading rate. The researchers demonstrated this by operating the fermentor at a daily loading rate between 0.08 and 0.15 pound per gallon (6.7 to 20 grams per liter) while varying

Above: In laboratory studies, researchers test effects of fermentation temperature and variations in mixture content on methane production. Vincent Varel, research microbiologist, pours manure mixture into bottles that simulate fermentation in the pilot plant. (678W728-29).

Left: Andrew Hashimoto, agricultural engineer, examines Methane Pilot Plant blue prints (678W725-37).

At the plant, Robinson records temperature in a hydrolysis tank, in which bacteria breaks down straw and manure mixture. Later, remaining straw practicles are screened out and the mix is sent to a fermenter, where methane is produced (1080W1216-22).

the temperature and associated loading rate.

Methane production was maximum at 140 °F (60 °C) and 3 days' retention time. This combination of temperature and retention time produced 90 percent more than at 95 °F (33 °C) and 6 days, 46 percent more than at 104 °F (40 °C) and 4.5 days, and 8 percent more than at 122 °F (50 °C) and 3.5 days.

While 140° has a slight advantage over 122° in methane output, maintaining the fermentor at that higher temperature may produce less net energy. About 130 °F (55 °C) appears to be the optimum operating temperature, according to the researchers.

Manure from cattle on high grain rations produces more methane than that from cattle on high roughage rations, Hashimoto says. The antibiotics, chlortetracycline and monensin, in the ration did not reduce methane yield, although monensin delayed the start of fermentation until the bacteria became adapted. Old manure from a dirt feedlot yields less methane than fresh beef manure.

The fermentor effluent is more valuable as a protein supplement for livestock than as a nitrogen fertilizer, the researchers say.

Composition of the amino acids making up the protein is comparable to that of soybean oil meal, says chemist Prior. In addition, nearly half of the effluent nitrogen is ammonia, a form that can be utilized by ruminants.

The effluent might be incorporated as is, into rations, or after centrifuging to remove most of the water. The high water content of uncentrifuged effluent limits the amount that can be added to the ration. And the 60- to 70-percent moisture content of the ration might, but has not, caused freezing in winter or spoilage in summer.

Centrifuging has the disadvantage of additional equipment cost, as well as loss of more than half of the nitrogen with the water unless a flocculating agent is used. The flocculants tested at Clay Center are expensive, and their suitability as a feed ingredient has not been determined.

Fermentation temperature is high enough to kill most disease-causing bacteria, Hashimoto says. But drugs, toxic elements, pesticides, and other environmental contaminants that might be in livestock manures are also matters of concern, as are aesthetic considerations.

The Food and Drug Administration (FDA) has neither sanctioned nor banned the feeding of livestock manures, either without or with processing such as fermentation.

When regulatory decisions have been made—and the design of systems for farm fermentation of manure has been perfected—more than 26 million tons (24 trillion kilograms) annually of easily collected livestock manure await conversion to methane and protein.

Dr. Andrew G. Hashimoto and associates are located at the Roman L. Hruska U.S. Meat Animal Research Center, P.O. Box 166, Clay Center, NE 68933.—(By Walter Martin, SEA, Peoria, Ill.)

Swine Dysentery Immunity Confirmed

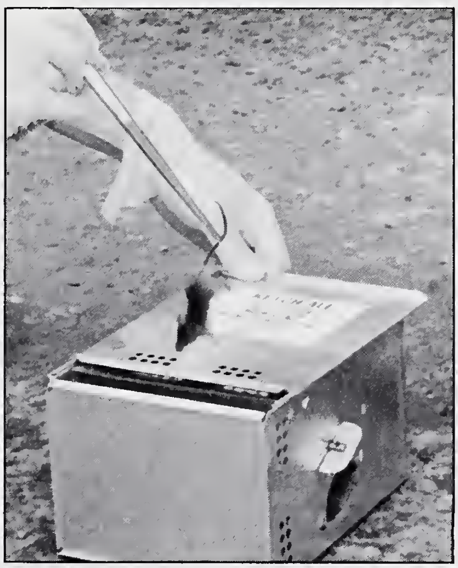
Research by SEA scientists has confirmed that pigs susceptible to swine dysentery develop immunity after exposure to pure cultures of the primary disease agent. This finding strengthens the possibility of developing an effective protective vaccine against the disease.

The primary agent, *Treponema hyodysenteriae,* had not been conclusively identified when previous investigators reported resistance to reinfection after the third or fourth exposure to infected feces. And some scientists question whether immunity indeed develops, since clinical signs of swine dysentery tend to reappear every 3 or 4 weeks in infected herds.

SEA microbiologist Lynn A. Joens first exposed 40 susceptible pigs to *T. hyodysenteriae.* The 29 pigs that survived were again exposed either 4 to 6, 9 to 13, or 16 to 17 weeks later. Twenty-seven of these pigs developed resistance, and detectable antibody levels remained high approximately 8 weeks after initial exposure.

If resistance to *T. hyodysenteriae* does not develop, vaccination would not be successful. Previous attempts to produce a useful level of protection by vaccination have been disappointing. But now there is hope.

Delbert L. Harris of Iowa State University, Ames, and SEA technician David H. Baum participated in the research. Dr. Lynn A. Joens is located at the National Animal Disease Center, P.O. Box 70, Ames, IA 50010.—(By Walter Martin, SEA, Peoria, Ill.)



Top and above: Wild mice can be more than an annoyance to pigs and pig producers—they may transmit swine dysentery. SEA microbiologist Lynn Joens baits an aluminum "live-trap" with rabbit food pellets to catch mice for laboratory analysis (0780W800-6). Joens removes his catch (078W799-11).

Above: To detect presence of *Treponema hyodysenteriae,* the primary agent of swine dysentery, Steve Puderbaugh separates colon from fecal material of wild mice (0780W798-5A).

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Agrisearch Notes

"Worst Case" Herbicide. A researcher, trying to evaluate the risks of herbicide runoff, hopes for a heavy rain soon after applying herbicide. This "worst case" situation occurred when SEA soil scientist William M. Edwards was conducting a study with glyphosate.

"When you apply 10 times the normal application rate of glyphosate one day and get a high-intensity rainstorm the next, you should expect some of the herbicide to show up in the runoff," says Edwards.

During 3 years of tests on several small watersheds at the North Appalachian Experimental Watershed, Coshocton, Ohio, Edwards tested 3 rates of glyphosate (Roundup) application during no-till seeding of corn or fescue on land that had previously been in either corn or pasture.

To create "worst-case" conditions, Edwards applied 8 pounds per acre (8.96 kg/ha) of glyphosate in 65 gallons of water, a much higher rate than normal. Measurements showed only 1.83 percent (0.15 pound per acre) of the herbicide was lost in runoff water from the storm the day after it was applied. Very little was lost thereafter. In fact, 99 percent of the herbicide lost following treatment was in the first runoff.

The watershed was 7.5 acres and averaged 15.8 percent slope. The highest concentration of glyphosate measured in runoff was 5.2 parts per million.

The next highest runoff loss, of those recorded, was 0.006 pound per acre (94 parts per billion) from a watershed treated at the 1-pound-per-acre rate.

"Herbicides such as glyphosate are coming into widespread use as more farmers shift toward less tillage," Edwards says. "A translocation herbicide moves from the leaves to the roots killing the entire plant, but it is not harmful to seeds being planted. It fits in perfectly with a no-till system where sod or weeds need to be killed at seeding time."

Edwards also evaluated runoff at application rates of 1 pound (1.1 kg/ha) per acre and 3 pounds (3.36 kg/ha) per acre.

Dr. William M. Edwards is located at the North Appalachian Experimental Watershed, State Route 621, P.O. Box 478, Coshocton, Ohio 43812.—(By Ray Pierce, SEA, Peoria, Ill.)

Natural Pest Control. Ethyl formate, a "natural" compound produced by fruits has been found to be an effective fumigant for killing green peach aphids on packaged lettuce and western flower thrips on strawberries.

The SEA research finding holds promise for improving Far East exporting and for helping the U.S. Army get fresh lettuce to its troops in Asia. Japan, with its strict import regulations, often condemns an entire van load of lettuce if insects are present.

The fumigants used today—hydrogen cyanide and methyl bromide—injure lettuce. Also, no official residue tolerance for methyl bromide has been established for strawberries.

Joseph K. Stewart, SEA horticulturist, U.S. Horticultural Field Station, Fresno, Calif., and Yair Aharoni, visiting plant physiologist from Israel, worked with the Army and lettuce growers to solve the insect problem on lettuce. The two cooperated on strawberry research using ethyl formate.

Ethyl formate has several advantages in addition to killing aphids and thrips: it has been used for a number of years to kill insects on dried fruits; it does not change the flavor or aroma of lettuce and berries; and it leaves no harmful residues.

Stewart and Aharoni fumigated packaged lettuce in a partial vacuum with 1.5 percent ethyl formate for 1½ hours and killed 100 percent of the insects. Also, by fumigating strawberries in a partial vacuum with ethyl formate at one percent concentration for 1 hour, they killed 100 percent of the thrips.

Vacuum fumigation reduces the exposure time required to kill insects, compared to fumigation at normal atmospheric pressure. Any procedure that will shorten exposure time is desirable, since lettuce and strawberries are both highly perishable.

Stewart cautions that although ethyl formate proved successful in this study, it does not mean that the Environmental Protection Agency (EPA) has cleared it for use on lettuce and strawberries.

Dr. Joseph K. Stewart is located at the U.S. Horticultural Field Station, 2021 S. Peach, Ave., Fresno, CA 93747. —(By Paul Dean, SEA, Oakland, Calif.)